



Xtallic[®] Corporation

XPROTECT[®]

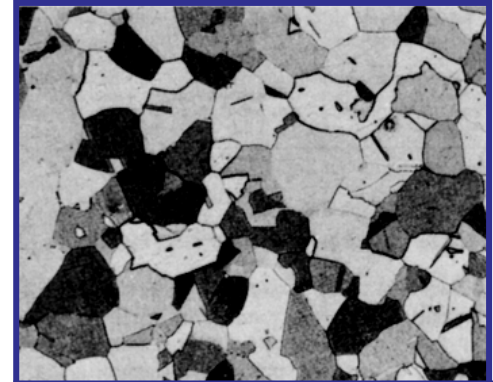
Marlborough, MA

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Xtalic Technology

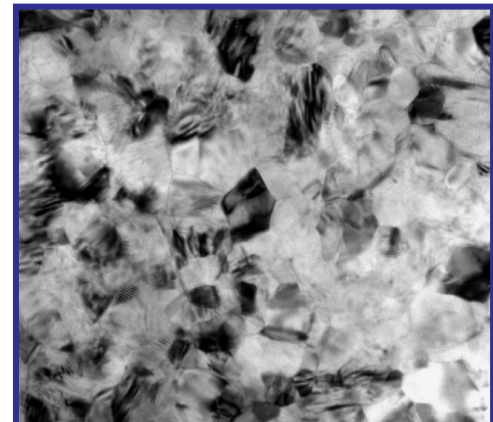
- Crystal (xtal) size and structure strongly influence materials properties
 - Wear
 - Corrosion resistance
 - Appearance
- Xtalic's technology dynamically controls crystal size and structure
 - Proprietary chemistry
 - Patented waveforms
- Xtalic's materials deliver dramatically enhanced performance

Traditional Metals



0.1 mm =
100,000 nm

Xtalic Metals

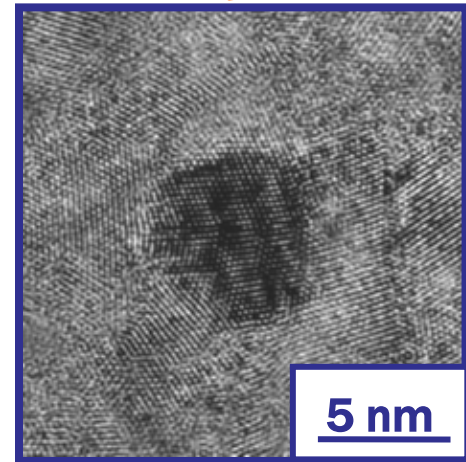
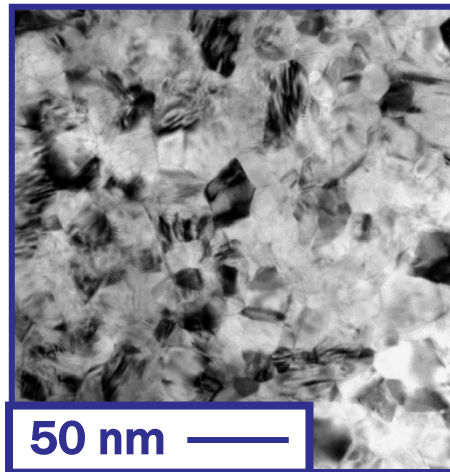
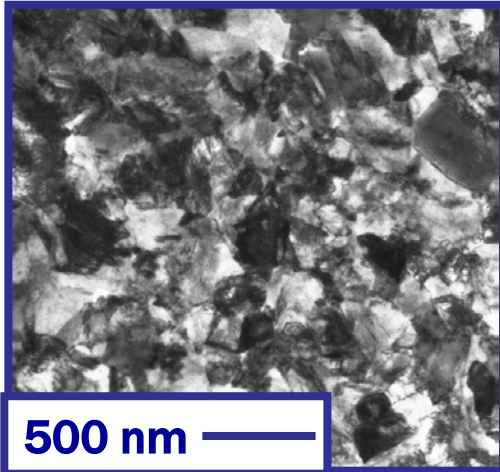
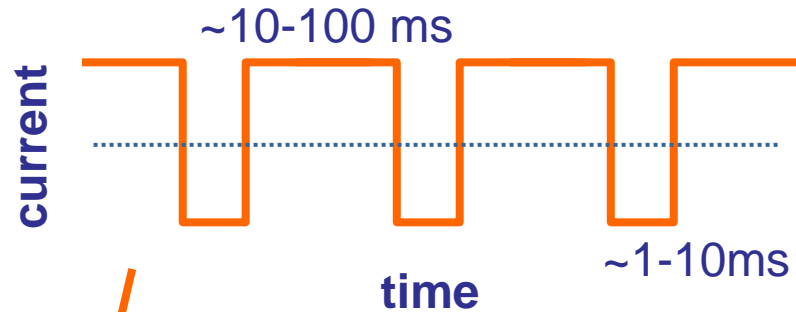


50 nm

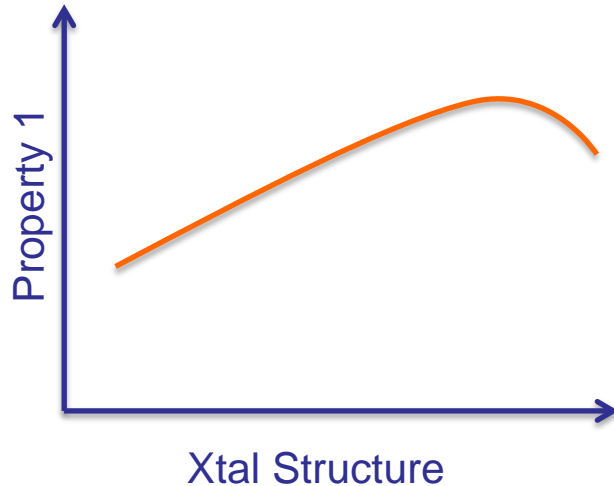
Xtalic Technology

Waveform control makes it possible to create tailored, nanocrystalline structures chosen to optimize performance

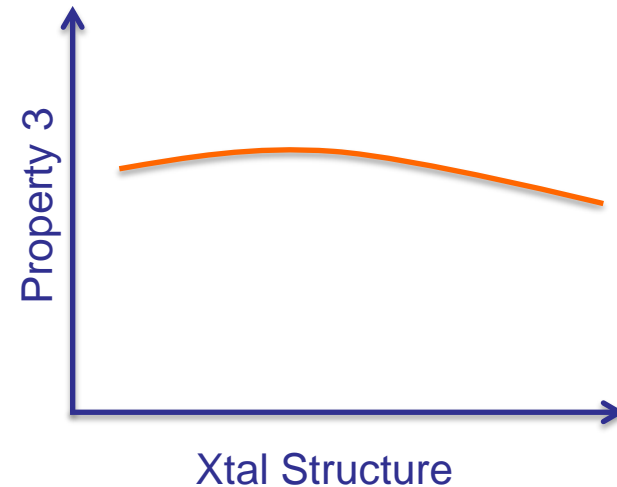
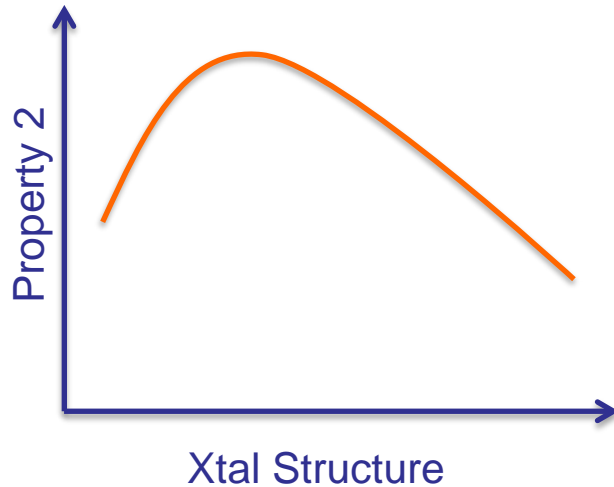
Xtalic Technology
pulsed current plating



Engineering the Optimum



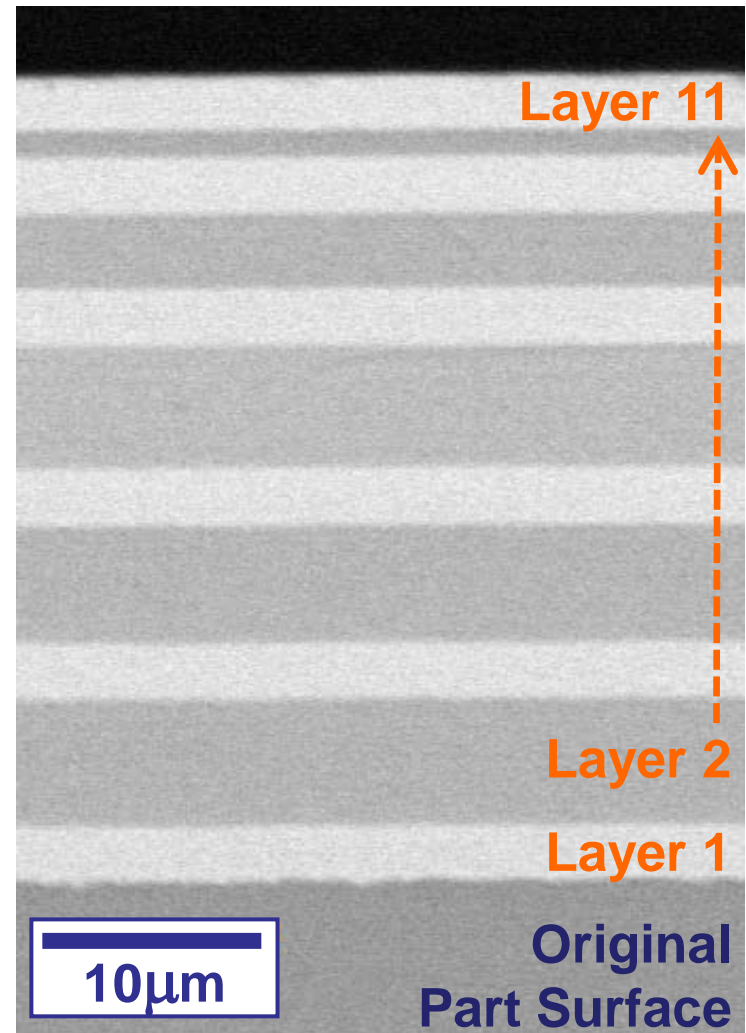
- Xtalic tunes the crystal structure to optimize properties
 - Wear
 - Corrosion protection
- A crystal structure can be selected that creates optimal properties within a single layer



Xtallic Technology

- Multiple layers with tailored properties are created in a single process step
- Dynamic control of crystal size and structure: crystal size, structure and alloy composition are variably controlled
- Superior composite performance is achieved

***Dynamic Nanostructure
Control™***



Xtalic Delivers

- Enhanced performance
 - Wear, Corrosion, Appearance
- Multiple properties in a single step
 - Potential for reduced thickness and material usage
 - Fewer steps required, less energy required
- Low environmental and worker health and safety impact
 - Replaces Hexavalent Chromium in a range of applications
 - In some cases, only workable alternative to Chromium
- Easily implemented production solution

Xtalic Application Areas

- **Decorative – XBRIGHT®**
 - Distinctive, high performance, environmentally friendly decorative coating
- **Electronics – XTRONIC®**
 - Very low porosity, slow diffusing barrier layer coating for electronics applications
- **Functional – XPROTECT®**
 - Engineering coating for functional wear + corrosion applications
(typically replacing hexavalent chrome or electroless Ni)

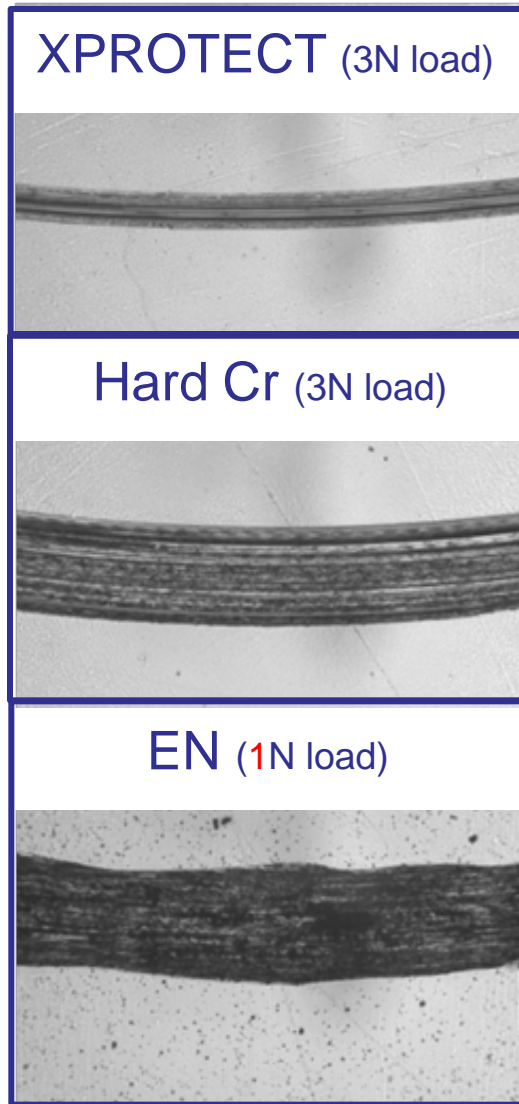
XPROTECT®

- Excellent corrosion protection
- Superior wear performance
- Improved properties under heat
- Replicates substrate R_a
- Good coating uniformity
- Chromium free



XPROTECT[®] : Superior Wear

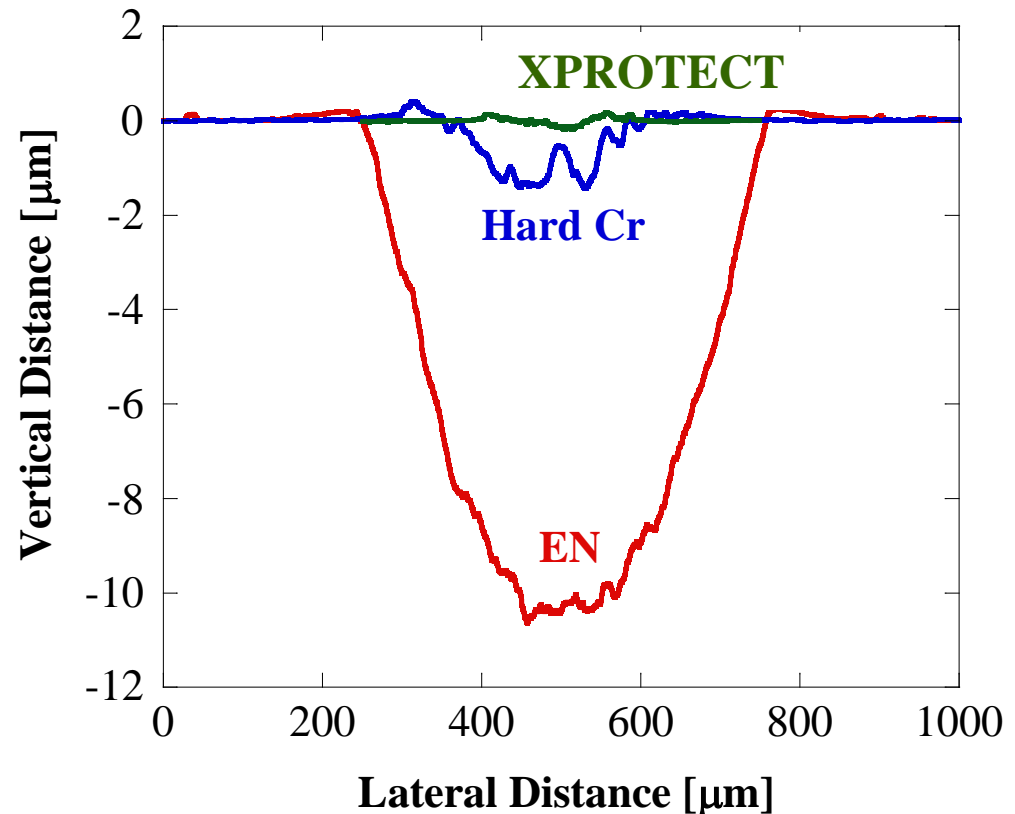
Light-optical micrographs of the
pin-on-disc wear tracks



Xtallic

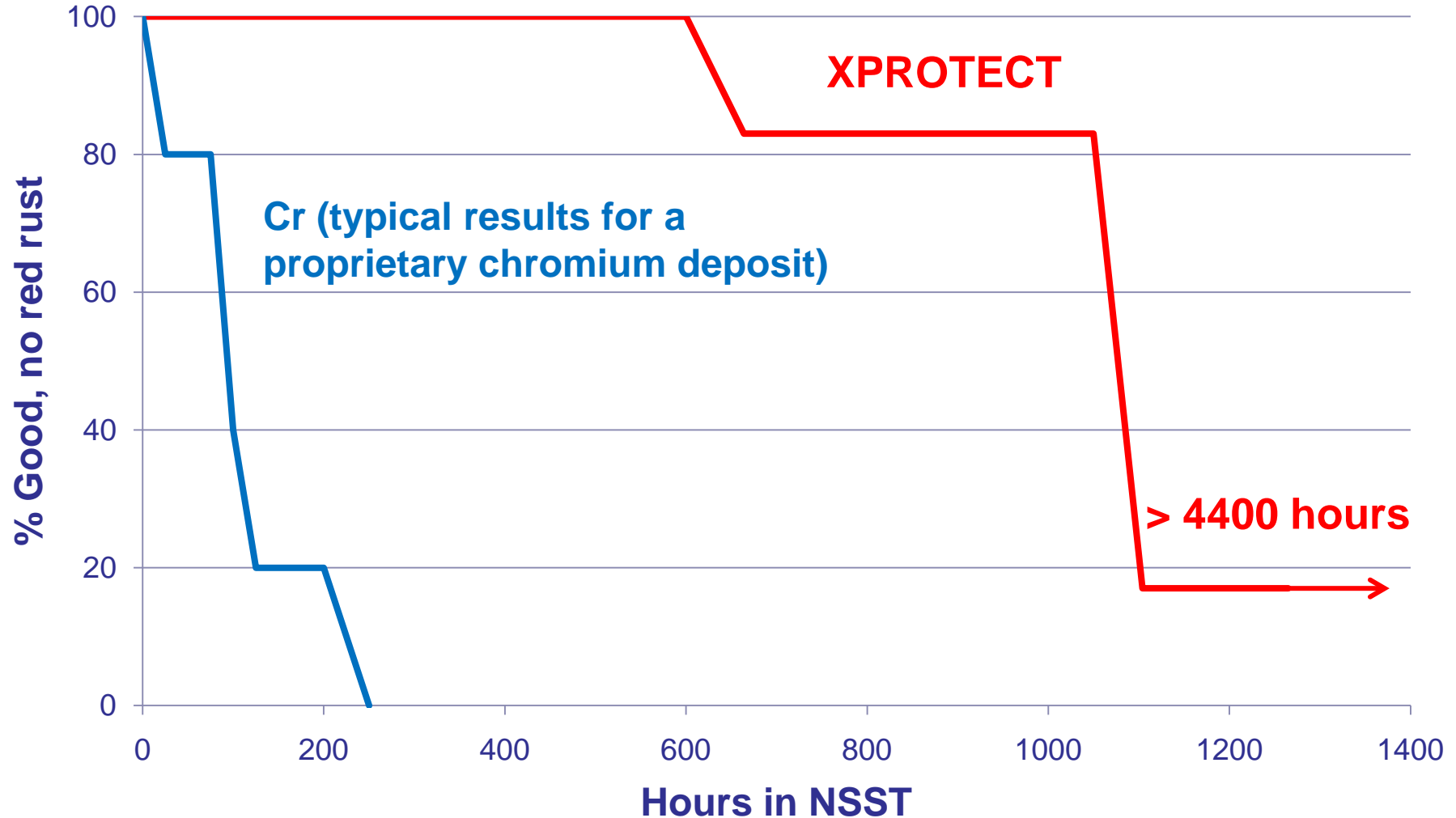
1 mm

Profilometer measurements
of wear tracks



XPROTECT[®] : Corrosion Protection

NSST (B117) of 25 microns of XPROTECT on 1566
precision ground rods with no post finishing

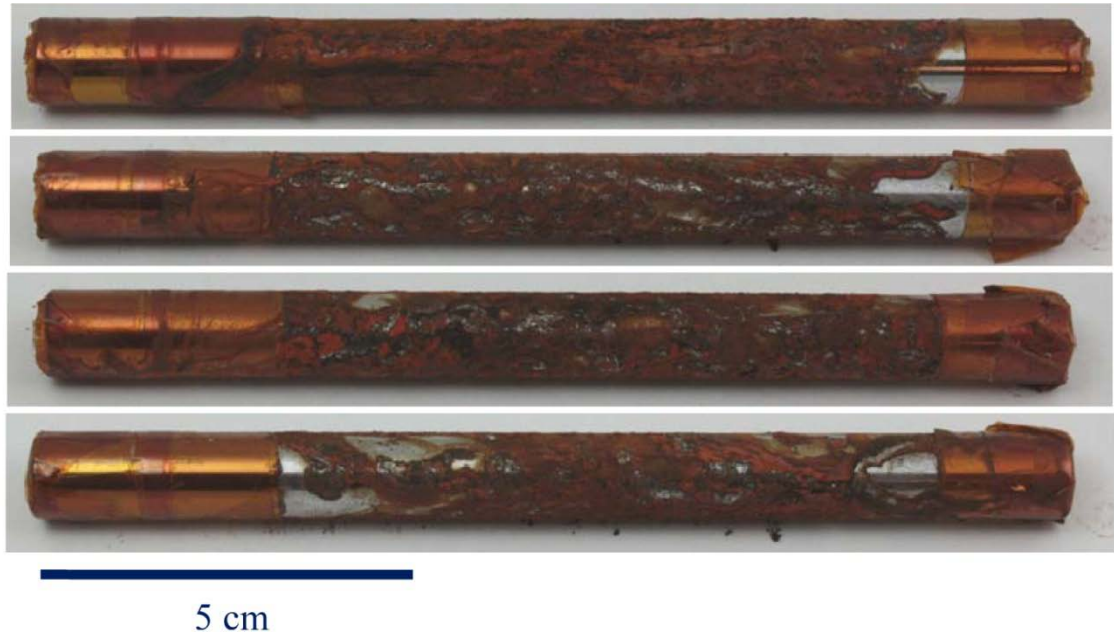


XPROTECT: Corrosion Protection

12 μm XPROTECT
coated steel shafts after
NSST, with exposure
times as shown.



12 μm hard Cr coated
commercial steel shafts
after 48 hours of NSST



XPROTECT – Hydraulic Shaft Example

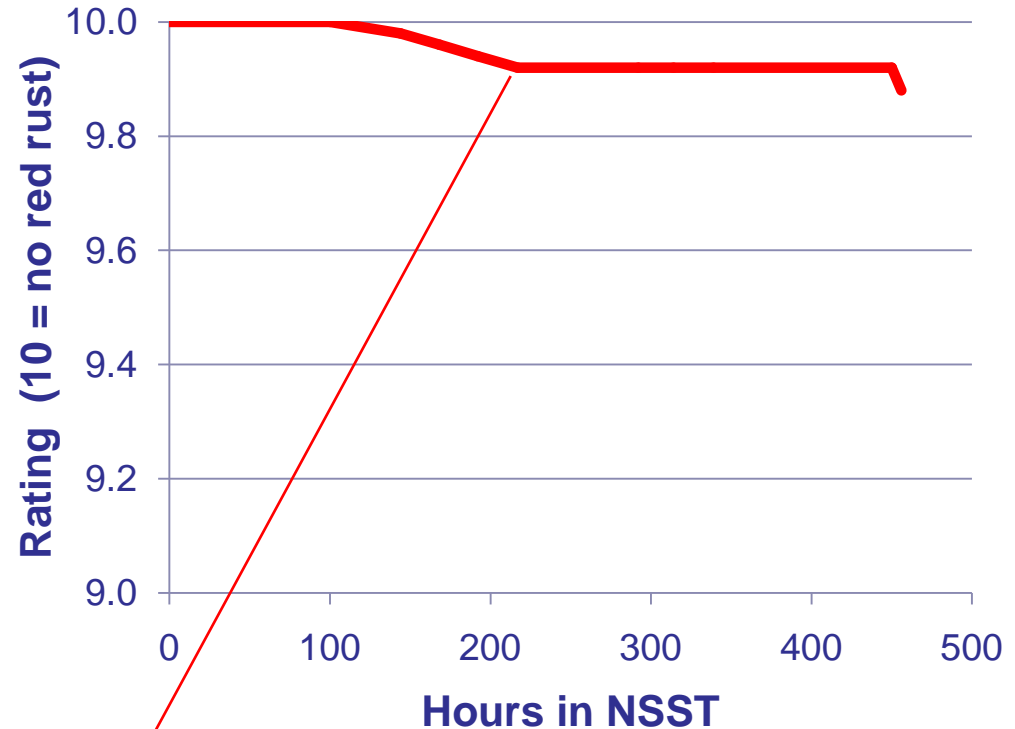
- 12 μm XPROTECT™ coated hydraulic shaft
- 500 hours of exposure to NSST
- No corrosion sites; rating = 10
- Sample size: 2"x12"



4 inches

XPROTECT[®] – Shock Absorber Example

- 25 µm XPROTECT coated shock absorber
- 500 hours of exposure to NSST
- Sample size: 0.62"x12"
- Significant defects from transport of unplated substrates led to isolated corrosion spots.



4 inches



XPROTECT® – Shock Absorber Example

Head to Head with Hard Chromium

- Compression adhesion test
 - Equivalent to Chromium
- NSST Corrosion test
 - XPROTECT > 744 hours
 - Chromium < 250 hours
- Russian Mud Test
 - XPROTECT pass
- Coefficient of friction with 300N Load

$$\left(\begin{array}{c} \text{XPROTECT with} \\ \text{no post-finishing} \end{array} \right) > 0.5 \left(\begin{array}{c} \text{Hard Chromium with} \\ \text{post-finishing} \end{array} \right)$$

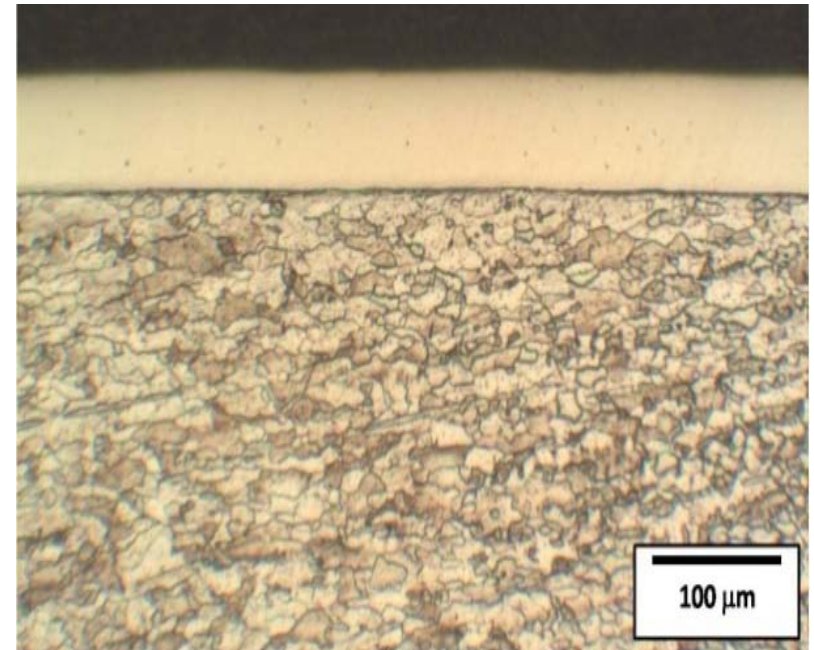
- Endurance wear testing
 - In Progress

XPROTECT[®] : Strengthens Under Heat

- Simple heat treat
 - Six hours at 191° C (375° F)
- Increased hardness
 - $HV_{100g} = 900 - 950$
 - 15% increase
- Stable structure
 - Key properties maintained or enhanced

Customer-Reported Sample Hardness Data

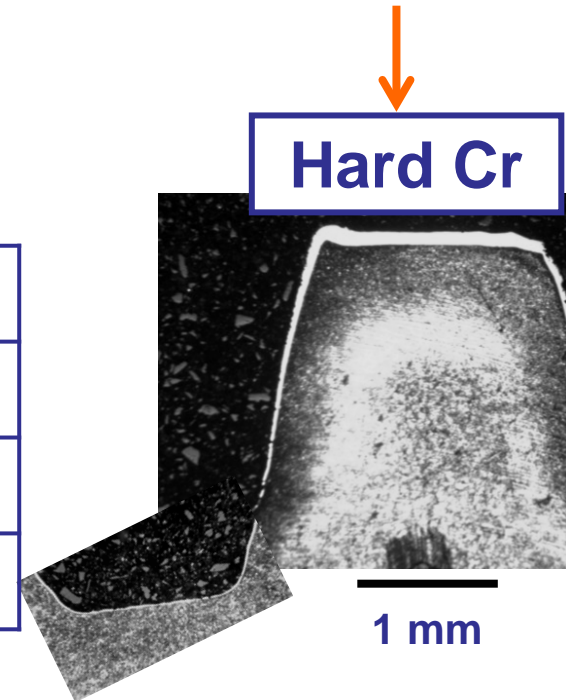
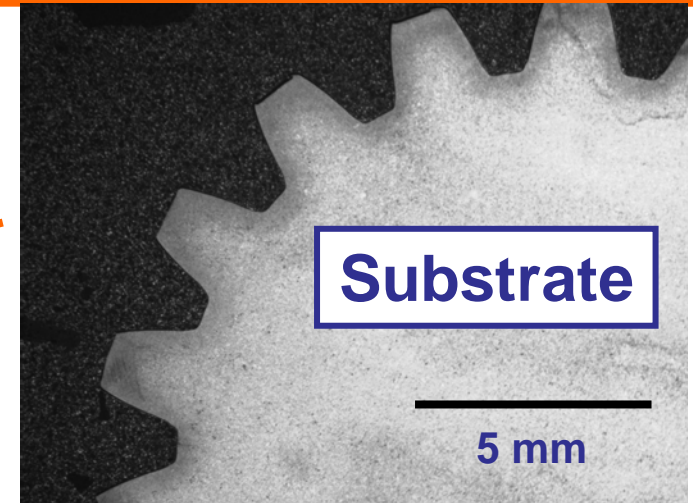
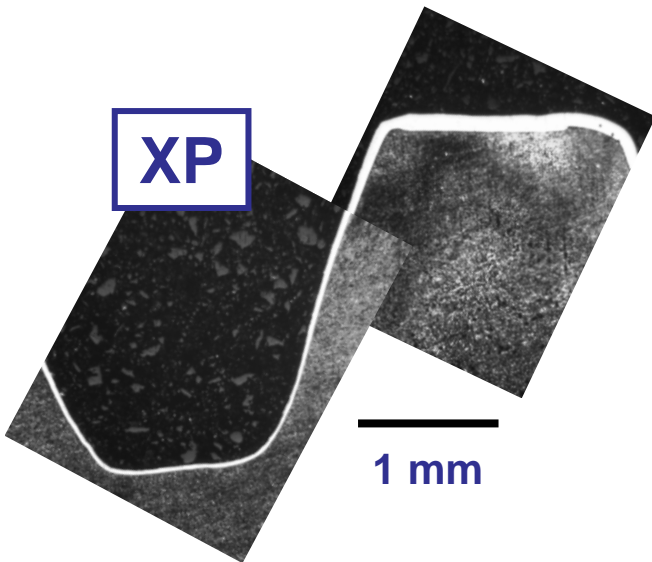
Sample #	Temperature	Time	Hardness, HVN100
1	none	N/A	679
2	375° F (191° C)	3	758
3	375° F (191° C)	8	840
4	375° F (191° C)	24	862
5	500° C	2	1040
6	500° C	5	1078
7	500° C	98	888



Plating Uniformity, Complex Geometry

Direct comparison, XP to hard Cr

Gear with aspect ratio 1.2:1



XP		Hard Cr
76	Avg peak thickness, μm	66
21	Avg valley thickness, μm	7.2
3.6	Peak to valley ratio	9.2

Hydrogen Embrittlement Resistance

- Notch tensile specimens plated with 50 μm of XPROTECT[®]
 - no post-bake
- Five samples tested per ASTM F519 (standard specimen, 1a.1)
- All samples passed loading requirement of 200 hours at 75% of ultimate tensile strength
- Samples *do not* require baking to pass the test



Plating at Scale: Evaluation Process

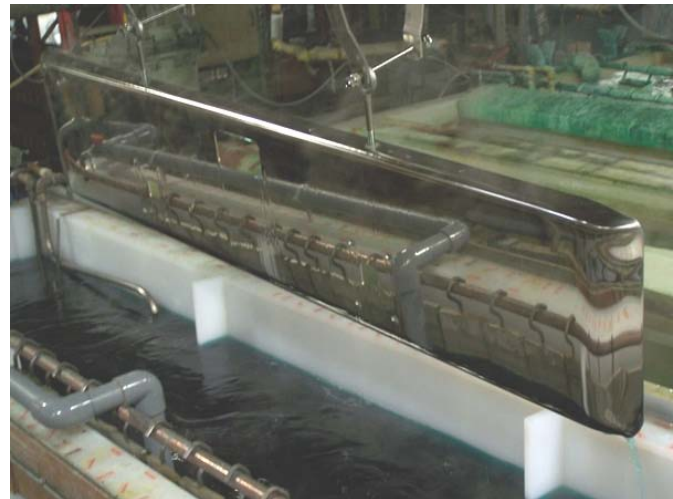


Xtalic pilot line in Marlborough, MA

- 375 liter (100 gallon) capacity
- Maximum part dimension up to ~50 cm (20 in)
- Part weights up to ½ ton

Xtalic partner shops

- Up to 1500 gal (6000 l) capacity
- Maximum part dimension up to ~4 m (12 ft)
- Part weights up to 1 ton



Xtalic: A Platform Technology

- Dynamically controlled structure allows tailored materials properties
- Multiple alloy systems maximize the accessible property sets
- Enhanced performance can be achieved across many markets
 - Aerospace
 - Automotive
 - Security
 - Medical Device
 - Home Appliances
 - Consumer Goods
 - Sports Equipment
 - Electronics
 - Communications
 - Industrial Equipment

Contact Us

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Conclusions

Performance properties are summarized in the table below:

Coating	Sliding Wear Resistance	NSST Corrosion Resistance	Surface Texture	Coating Distrib.
XPROTECT [®]	++	+++	+	+
XPROTECT [®] ,HT	++	+++		
Cr	+	0	-	-
EN-P↑	-	++	0	+++
EN-P↑, HT		+		

XPROTECT[®] : Superior Wear

Non-lubricated Pin-on-Disc Apparatus with a Tungsten Carbide Pin

Coating	Load [N]	COF	Penetration depth [μm]	Wear rate [mm³/hr]	Relative Wear rate
XP	3	0.5	0.2	1.0x10 ⁻³	1
XP, 400°C/4hr	3	-	0.1	4.0x10 ⁻⁴	0.25
Hard Cr	3	0.85	1.5	2.3x10 ⁻²	23
EN (high P)	1	0.62	10.5	2.9x10 ⁻¹	290

XPROTECT[®] Corrosion Protection

Hard Chromium

- Failures were rapid at 12 μm **< 4 hours**
- Functional chromium deposits with a thickness of 25 μm (1 mil) will last in NSST for between (*Jones*) **10 and 500 hours** depending upon pre-finishing, plating and post finishing.

XP Coating

- XP coatings with between 12 and 25 μm (0.5 to 1.0 mils) lasted in NSST for between
 - **350 and > 4400 hours**
- When the coatings did corrode, the corrosion sites were typically very small and did not expand rapidly.

XPROTECT[®] Corrosion: Acid Data

Performance properties XPROTECT[®] vs. Cr

Coating	Corrosion Rates, mm/year		
Acid 10% (v/v)	HCl	H ₂ SO ₄	HNO ₃
Temp, C	22	58	58
XPROTECT (Immersion)	0.0030	0.35	TBD
XPROTECT (EC) (minimum)	0.054 ¹	0.017 ¹	0.071 ¹
Cr ²	rapid	250	0.3

¹Room Temp - 5 day test

²Corrosion data from Uhlig

XPROTECT[®] : Corrosion Protection

Corrosion Panels after 1000 hrs B-117 Exposure
(Note: Panel 1 was exposed for only 24 hrs)

Sample #	Hours Exposed	Observation
1	24	Red rust
2	>1000	No red rust
3	>1000	10 isolated spots (small)
4	>1000	No red rust
5	>1000	4 isolated spots (small)
6	>1000	No red rust



Plating Uniformity, Shaft/Rod

- Sample dimensions: 25 mm diameter and 300 mm length
- Tank anodes used on each side of part; no conforming anodes
- 300 mm anode to cathode separation
- Plating time: 1 hour

Location around rod (degrees)	Thickness (μm)
0	41.9
90	40.9
180	39.9
270	40.6
Average	40.9

- Uniformity around the circumference (eddy current): ±2.4%